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Demand For Satellite-Provided Domestic Communications Services to the Year 2000

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DEMAND FOR SATELLITE-PROVIDED DOMESTIC COMMUNICATIONS

SERVICES TO THE YEAR 2000

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SUMMARY

Three fixed service telecommunications demand assessment studies were completed in 1983 for NASA by The Western Union Telegraph Company and the U.S. Telephone and Telegraph Corporation. These studies provided forecasts of the total U.S. domestic demand, from 1980 to the year 2000, for voice, data, and video services. That portion that is technically and economically suitable for transmission by satellite systems, both large trunking systems and customer premises services (CPS) systems was also estimated. In order to provide a single set of forecasts for use in NASA communications program planning, a NASA synthesis of the above studies was conducted and is the subject of this report. The services, associated forecast techniques, and data bases employed by both contractors were examined, those elements of each judged to be the most appropriate were selected, and new forecasts were made. The demand for voice, data, and video services was first forecast in fundamental units of call-seconds, bits/year, and channels, respectively. Transmission technology characteristics and capabilities were then forecast, and the fundamental demand converted to an equivalent transmission capacity. The potential demand for satellite-provided services was found to grow by a factor of 6, from 400 to 2400 equivalent 36 MHz satellite transponders over the 20-year period. About 80 percent of this was found to be more appropriate for trunking systems and 20 percent for CPS.

INTRODUCTION

Three fixed service telecommunications demand assessment studies were completed in 1983 for NASA by The Western Union Telegraph Company (WU) and the U.S. Telephone and Telegraph Corporation (UST&T), a subsidiary of the International Telephone and Telegraph Corporation (refs. 1 to 3). These studies estimated the U.S. domestic demand for voice, data and video services to the end of the century including that portion potentially addressable by satellite systems, both customer premises service (CPS)-type systems and large trunking systems. This work was done as part of a continuing effort within the NASA communications program to provide guidance for the development of enabling communications satellite technologies satisfying the communications demands of 10 to 20 years hence.

Two of these studies (one by UST&T and the other by WU) focused on identifying the potential demand for customer premises-type satellite communications systems. The third study (by WU) quantified the demand potential for large trunk-type satellite system applications. In the UST&T study, estimates were developed of the overall U.S. domestic communications traffic (excluding local nontoll traffic) to the year 2000, the market for satellite services, and that

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portion of the satellite market that could be CPS, at two availability levels,[1] 0.999 and 0.995. Peak-hour traffic, line speed, and transmission efficiency characteristics for each traffic component were considered, and the final results were presented in terms of peak-hour megabits/second. The WU studies provided forecasts of the overall U.S. domestic demand (excluding local nontoll traffic), the portion distributed among the 313 Standard Metropolitan Statistical Areas (SMSA's), and the satellite-addressable portion for trunked and CPS systems. Estimates of the demand for trunking and customer premises services were made in two ways: (1) considering them as operating together in a competitive environment such that the sum of the two constitute the overall satellite-addressable demand; and (2) as a limiting case, considering them as operating independently of one another, i.e., without competition from one another. In the case of the trunked systems, estimates of satellite-addressable traffic were made for satellite systems operating at C, Ku-and Ka-bands and for the combination yielding the maximum satellite-addressable demand. For the CPS systems, a similar maximum traffic combination among the bands was made and then an estimate was made for Ka-band alone at two availability levels, 0.999 and 0.995. The final results were quoted in two ways: (1) in basic units of half circuits for voice, peak-hour megabits/second for data, and number of channels for video; and (2) in terms of equivalent 36 MHz transponders for each service. Technology forecasts such as the percent of analog and digital traffic carried, video compression, transponder capacity, and gradual replacement of terrestrial plant by satellite, were made to convert the basic service demand into equivalent transmission capacity requirements in terms of 36 MHz transponders. A recent NASA Technical Memorandum (ref. 4) presents a summary and comparison of the results of these studies.

The two study contractors, UST&T and WU, conducted their studies entirely independent of one another. Independent approaches to the forecasts were taken and different ground rules and assumptions were employed. Consequently, the final results of their studies are not directly comparable in all cases. In order to provide a single set of forecasts with consistent underlying assumptions, a NASA synthesis of the above studies was conducted and is the subject of this report. The services and associated forecast techniques employed by both contractors were examined. Where it was apparent that certain aspects of either of the contractors' studies had been performed in greater depth or were judged to be more realistic, these were adopted or weighted more heavily in the NASA forecast. In addition, influential trends and events occurring since the contractors' studies were performed were incorporated in the NASA forecast. Examples include the deregulation of the telecommunications industry, reduction of allowable satellite orbital spacing to 2°, emergence of low-powered direct broadcast television services in the fixed-services satellite band, and others. Thus, for the NASA synthesized forecast, a complete set of voice, data, and video services was selected, the most appropriate forecast methodology and rationale unique to each service was selected, and forecasts to the year 2000 were made. The NASA forecast consists of estimates of the overall U.S. domestic telecommunications demand, the portion attributed to the 313 SMSA's, the satellite-addressable demand for both CPS and trunking services, and Ka-band CPS. Thirty-five services were considered; 9 voice services, 17 data services,

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[1]Service availability refers to the probability of the satellite communications link not being attenuated beyond acceptable limits due to atmospheric conditions.

and 9 video services. Expected technology advances, analog/digital mixes, and traffic and transmission characteristics were also considered . The forecast results are presented in terms of basic traffic units of voice half circuits, megabits/second (data) and video channels and their equivalents in terms of 36 MHz transponders.

SERVICES

Figure 1 provides a list of the voice, data, and video services included in the NASA forecast. The NASA forecast is inclusive of all the services considered by both contractors. Nine voice, 17 data, and 9 video services are included. A brief definition of each service is given below. Note that since one of the study objectives was to identify satellite-addressable demand, local toll traffic was not evaluated or included in the demand estimates. More details may be found in the referenced studies.

Voice Services

The nine voice services are comprised of toll residential and business telephone services, private line, mobile telephone, and several radio services. The nine voice services are defined as follows:

1. Message Toll Service (MTS) - Residential - This is long distance, metered, switched telephone service for the private consumer through the networks of domestic communications carriers.

2. MTS - Business Including WATS - This represents use of the metered, switched service networks (long distance) by the business community. It includes usage of Wide Area Telephone Service (WATS).

3. Private Line - Private line service represents the leasing of a dedicated telephone circuit by a customer for his exclusive use.

4. Mobile Telephone - This represents the long distance component of mobile radio traffic carried by the switched network.

5. Public Radio - National Public Radio (NPR) carries a wide variety of dramatic, specialized and educational programming.

6. Commercial and Religious Radio - Commercial radio networks; primarily news and entertainment programming and networks devoted exclusively to religious programming.

7. Occasional - Special event coverage creating a demand for occasional usage of additional radio channels.

8. CATV Music - CATV systems are now providing a few channels for music in addition to their regular video service.

9. Recording Channel - A service providing very high quality music suitable for recording.

It may be noted that over 99 percent of the voice demand is generated by the residential MTS, business MTS, and private line service categories. Another voice service now being introduced, and one that will be an important feature of the "office of the future," is voice-store-and-forward. Voice-store-and-forward is similar to "mailbox" and electronic mail services except that voice messages are stored and retrieved instead of text. This service was not forecast separately, but its influences are reflected in the MTS and Residential and Business forecasts. It actually has a slight negative effect on the forecasts because it reduces repeated calling attempts to unanswering stations.

The MTS, Private Line, and Mobile Telephone services are conventional voice telephone services and occupy bandwidths normally associated with such services. The Radio services occupy a much larger bandwidth/channel. For consistency in quantifying the voice services in terms of the standard units of voice half circuits, the radio channels have been converted to equivalent voice half circuits (80 half circuits/radio channel).

Data Services

The 17 data services are organized into two computer-type services (low speed terminal/CPU interactions and high speed CPU/CPU interactions) and message-type services.

The terminal/CPU services are defined as follows:

1. Data Entry - Primarily updating of existing data bases. Transmission speeds range from 2.4 to 56 Kbps.

2. Remote Job Entry - Computer processing where the operator is at some location other than the computer facility. Transmission speeds are on the order of 1.2 to 9.6 Kbps.

3. Inquiry/Response - Terminal operations of a more urgent nature such as airline reservation systems and stock quotations. Transmission speeds generally range from 1.2 to 9.6 Kbps.

4. Timesharing - Timesharing is the shared use of centrally located computer facilities by several operating entities. Transmission speeds range from 1.2 to 9.6 Kbps.

5. Point-of-Sale - Payments made in consumer transactions are entered directly into the banking system instead of being made by credit card or check. Transmission speeds are typically 4.8 Kbps.

6. Videotex/Teletext - An umbrella term covering a variety of interactive and noninteractive consumer information services displayed on the home video screen. Information may be transmitted in the vertical blanking interval of a television signal or by dial-up over the telephone system.

7. Telemonitoring - Telemonitoring refers to the electronic monitoring from a central location of the status or condition of a device at a remote and usually unoccupied location.

The CPU/CPU services are defined as follows:

8. Data Transfer - Transfer of information from one storage bank to another. Transmission speed is usually 56 Kbps or higher.

9. Batch Processing - Batch processing of information such as daily sales orders and weekly payroll information usually on a regularly scheduled basis. Transmission speed is usually 56 Kbps or higher.

The Message services comprise a variety of data speeds. Electronic mail and some facsimile make use of 56 Kbps facilities and higher while a number of the other message services are limited to telephone line speeds (up to 9600 bps). The services are described as follows:

10. U.S Postal Service Electronic Mail Switching System (USPS EMSS) - The volume of mail transferred electronically over projected USPS systems. Although this particular service has been discontinued by the USPS since the studies were completed, the same demand potential exists and this service is expected to be provided by private sector entities.

11. Mailbox - In Mailbox service, messages are stored in a central computer which the recipient accesses at his convenience to obtain his messages.

12. Administrative Message Traffic - Generally short person-to-person messages usually of an intracompany nature.

13. TWX/Telex - Slow speed (45 to 150 bps) switched teletypewriter services provided by AT&T and Western Union, respectively.

14. Facsimile - Three types of facsimile are considered:

a. Convenience Facsimile - slow to medium speed, i.e., 2 to 6 min/page (9600 to 1200 bps).

b. Operational Facsimile - medium to high speed, 1 sec to 2 min/page, requiring relatively wideband transmission facilities (1.544 Mbps to 9.6 Kbps).

c. Special Purpose Facsimile - High resolution facsimile such as used for fingerprint transmission by law enforcement agencies or the transmission of maps by the National Weather Service.

15. Mailgram/Telegram/Money Order - Mailgram is an electronic mail service provided by Western Union combining Western Union's long haul transmission facilities with the U.S. Postal Service's local delivery service for next business day delivery anywhere in the U.S. and Canada. Telegram is another Western Union service used for urgent messages or to make an impact. The money order is a means of electronically transmitting funds, generally relatively small payments.

16. Communicating Word Processors - A communicating word processor (CWP) adds communication capability to a printer/keyboard or CRT-based word processing system. This allows the input to be prepared on one system and sent via communication links, at speeds ranging from 1.2 to 9.6 Kbps, to another system for output, editing, or manipulation. The advantage to the user is the

ability to transmit original-quality documents with format control similar to letter and memo correspondence.

17. Secure Voice - Communications security for voice transmissions using voice scrambling and digital voice encryption techniques.

Video Services

The nine video services are classified into two categories: those of a broadcast nature and videoconferencing. Seven services are in the broadcast category and two are videoconferencing.

The broadcast services are defined as follows:

1. Commercial Network - Transmissions by the three commercial video networks: ABC, CBS and NBC.

2. Noncommercial Network (PBS) - Transmissions by the Public Broadcasting Service.

3. CATV - Transmissions for distribution by cable television systems. Although not explicitly considered as a separate category, low to medium powered direct broadcast satellites (DBS) operating in the fixed services frequency bands are included in this category.

4. Occasional - Occasional video refers to special event coverage or broadcasting of a nonregularly scheduled nature. Commercial and noncommercial broadcasters as well as CATV operators make use of occasional video.

5. Educational - Educational video services are classified into three categories:

   a. Intrastate - includes higher education, adult education and extension courses conducted at remote campuses or company sites some distance from the primary educational center, but generally within state boundaries.

   b. Interstate - facilities serving educational organizations with broader reach, e.g., executive seminars, training programs, professional training, etc.

   c. Specialized Programs - specific applications in agriculture, consumer education, vocational, etc.; generally intrastate.

6. Public Service - In the NASA forecast, telemedicine is the only service included in the Public Service category. UST&T included a public affairs service in this category but this is included under one-way videoconferencing in the NASA forecast. Telemedicine refers to the extension of diagnostic and emergency treatment procedures to remote areas by medical practitioners in central locations with the assistance of local paramedical attendants.

7. Recording Channel - A pay service providing video material for home recording, generally in the off-peak hours.

The videoconferencing services are:

8. One-Way Videoconferencing with and without interactive voice response - This includes general business use, medical, public affairs, forums, opinion polls, consumer and related activities. Video transmission speed varies from fixed frame over voice grade lines (4800 bps for analog circuits or 56 Kbps if digital transmission is used) to high definition video requiring large bandwidth (48 to 96 Mbps data rate).

9. Two-way Videoconferencing - Two-way video for conducting meetings and conferences. Speeds vary from fixed frame (slow scan) to full motion.

FORECAST APPROACH

A prime objective of the WU and UST&T studies was to quantify the amount of communications traffic that potentially could be transmitted over satellite systems. This is that portion of the total U.S.-generated communications traffic, that due to its system economics, technical and user characteristics, would cause satellite systems to be the preferred transmission means. In this forecast it is termed the "satellite-addressable traffic." It is important to emphasize that the satellite-addressable traffic is <u>not</u> an estimate of what will be captured by satellite systems, but is an estimate of what <u>could</u> be captured by satellite system operators. It is the amount of traffic that is potentially viable for transmission over satellite systems. The traffic potential for two types of satellite systems was considered: (1) large trunked systems suitable for carrying traffic among the 313 SMSA's; and (2) customer premises services (CPS) systems, having earth stations located on the users' premises, possibly shared with other local users. The total traffic potential for these two systems was derived in the context of both systems in operation and competing for all categories of traffic. The overall satellite-addressable traffic is the sum of these two traffic potentials. Because the way in which CPS systems may ultimately develop and compete with trunking systems is highly uncertain, the traffic potential of trunking systems alone (assuming CPS systems will not exist) was also derived. A comparison of this scenario with the overall satellite-addressable demand provides an understanding of the possible impact of CPS systems on the overall satellite-addressable demand and the trunked portion of that demand. Also, as a limiting case, the traffic potential of CPS systems alone was derived. Although the CPS alone case, i.e., no competition from trunking systems, is not realistic, it was included in order to provide additional insight into the nature of CPS demand. The satellite-addressable traffic was also considered in two other ways: (1) in the context of a mix of systems operating in all three satellite allocated frequency bands, C, Ku, and Ka-bands, for that mix providing the maximum satellite traffic potential; and (2) in the case of CPS alone, the maximum traffic potential of Ka-band CPS systems, with no competition from the other two. A service availability of at least 0.999 was assumed for all the above trunking and CPS scenarios plus a lower availability of 0.995 for the CPS Ka-band cases.

The satellite-addressable traffic was derived by first estimating the total domestic U.S. traffic for 1980, excluding local nontoll traffic. This total traffic was then forecast for the years 1990 and 2000 by using forecast methods selected from the two contractors' forecast methodologies, along with more recent information, as discussed earlier. The intra-SMSA toll traffic component was then removed (the assumption being that this is too short haul

for potential satellite traffic) to define the "Net Long Haul" (NLH) traffic. The NLH traffic forecast then formed the basis for deriving the satellite-addressable market. In the case of large trunking systems, the NLH traffic was further reduced by the removal of the "hinterland traffic" or traffic component to or from a non-SMSA area, as this traffic would not likely be carried by trunking systems. A certain amount of traffic is not suitable for satellite transmission due to time delay, somewhat lower availability levels, and other factors. This traffic component was also removed from the NLH traffic for both CPS and Trunking. Then CPS and trunking system concepts incorporating technologies expected to be available in the time period of interest were developed and costed, and the cost to provide service was derived. Since the cost to provide satellite service is distance insensitive whereas the terrestrial cost to provide service is distance variant, there is a distance ("crossover") beyond which transmission by satellite is economically favorable. The amount of NLH traffic transmitted beyond this crossover distance for each service was then determined and the aggregate was defined as the overall satellite-addressable traffic. For MTS voice and all of the data, an additional amount was excluded from the satellite-addressable traffic estimates to reflect the effect of the installed terrestrial plant-in-place.

The crossover distances and consequently the magnitudes of the satellite-addressable traffic are sensitive to assumptions regarding alternative terrestrial system economics. To better understand these effects, WU did an additional study of the sensitivity of the satellite-addressable traffic to changes in service cost, and the results are reported in reference 5. One area where service costs are changing rapidly is fiber optics. Although fiber optic transmission technology was considered by both WU and UST&T as a terrestrial competitor with satellite systems, rapid advances in this field since the studies were done may make fiber optic systems more competitive with satellite systems than earlier envisioned. Although the results of the WU sensitivity study can be used to examine the impact of price reductions in general, NASA is currently initiating a study to assess specifically the impact of expected improvements in fiber optic technology.

In developing the forecasts, the voice, data, and video traffic estimates were derived first in their natural source units such as number of messages for voice, bits/year for data, and channels for video. Service usage statistics such as message length, overhead, peak-hour factors, and transmission efficiencies were then considered to give an estimate of the equivalent transmission capacity required to carry the traffic; voice in peak-hour half circuits, data in peak-hour megabits/second, and video in numbers of peak-hour channels. To convert these capacity requirements to transponder requirements, estimates were first made of factors expected to influence transponder throughput capabilities. These included the likely mix of digital and analog voice traffic, coding advancements permitting the reduction of required bit rate/digital voice channel, companded single sideband techniques for analog voice, multiplexing advancements permitting greater data rates/unit bandwidth, and video compression improvements. Trunking systems were assumed to operate with a mix of analog and digital techniques, whereas CPS systems were assumed to be all digital. With these factors, the transmission capacity estimates were then converted into equivalent 36 MHz transponders. Figure 2 provides a flowchart of the satellite-addressable traffic derivation process described above.

FORECASTS

The discussion of the forecasting of each of the three service categories is organized according to the format of figure 3. The Total and Net Long Haul forecast derivations are discussed first, followed by the Overall Satellite-Addressable, the Trunking and CPS segments of the Overall Satellite-Addressable, then the Trunking Alone, CPS Alone, and Ka-band CPS Alone. The CPS estimates are comprised of that combination of shared and unshared earth stations[2] that maximizes the demand potential and, additionally, for Ka-band CPS, the demand potential for unshared earth stations alone. Also, for Ka-band, the demand for a lower service availability of 0.995 was estimated.

Voice Services

Total and Net Long Haul Voice Demand

MTS residential, business, and WATS voice services. - The Message Toll Service (MTS) components (residential, business, and WATS) were forecast on the basis of information from references 1 to 3, Bell Long Lines statistics and other common carrier statistics. These statistics provided the total number of interurban toll messages for business, residential, and WATS for both interstate and intrastate calls for the year 1980. Message statistics such as call length (seconds), and percent allowance for overhead (busy signals, misdialed calls, any connect time beyond the message length) were also obtained and used to calculate the total call-seconds for each traffic component for 1980. The call distribution/24 hr day for each service was examined and the peak busy hour noted, i.e., the hour during the day where the maximum of the sum of business, WATS, and residential traffic occurs. The peak busy hour is a direct determinant of the number of circuits required. Although residential traffic peaks later in the day than business and WATS, the sum of the three traffic distributions peaks at about the same time as business and WATS, and this defines the busy hour factor or peak-to-average factor for determining the overall circuit requirements. The call-second information, peak-hour factors, and number of days/year applicable to each service, were combined to obtain the number of voice circuits required for each service during the daily busy hour. This was then increased about 5 percent to account for acceptable call blocking characteristics. This formed the basis of the 1980 U.S. domestic MTS circuit requirement and is analogous to the WU "Net Long Haul" and the UST&T "Overall" estimates. To obtain estimates of the "Total" U.S. MTS circuit requirement including non-SMSA traffic, the NLH estimates were scaled by the WU numbers (i.e., by the ratio of the WU Total/WU NLH). For making the forecasts, the WU and UST&T growth rates were reviewed and adjusted for more recent considerations of the probable influences of the deregulatory environment and these adjusted values were used to project the 1980 figures to 1990 and 2000.

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[2] With CPS two concepts of ground segment operation are considered: (1) a mixture of earth stations that are shared by a number of users and some that are dedicated to a single user; and (2) dedicated or unshared usage only.

Private line voice. - A comparison of the private line derivation methodology of WU and UST&T indicated that the UST&T forecast for domestic, private line traffic is similar to the WU "Trunking Net Long Haul" in that it includes inter-SMSA traffic only. The estimates are, in fact, within a few percent of one another. Therefore, for the NASA forecast, it was felt that an average of the WU and UST&T estimates for each base year, 1980, 1990, and 2000, would be sufficient. This average, then, constitutes the NASA forecast for the Net Long Haul (Trunking) private line traffic. The NLH from which the CPS estimates are derived is just the trunking NLH plus the hinterland traffic. The NASA NLH was constructed by scaling the NASA trunking NLH in proportion to the difference between the WU NLH (including hinterland traffic) and WU trunking NLH estimates. The NASA "Total" was obtained by scaling the NASA NLH by the corresponding WU estimates as in the preceding paragraph.

Mobile telephone services and broadcast radio services. - WU's forecasts for the long haul, switched network portion of mobile telephone services and the various radio services were adopted as the NASA forecast since the UST&T forecast did not include these categories.

The above demand estimates were summed to obtain the Total and Net Long Haul U.S. domestic voice demand presented in table I.

Satellite-Addressable Voice Demand

As described earlier, WU and UST&T derived the satellite-addressable traffic from the net long haul traffic in two steps. First, for each service, they removed that amount of traffic they felt to be unsuitable for satellite transmission. Next, they derived crossover distances or distances beyond which transmission by satellite is more economical. The distance distribution of the traffic remaining after the first step was examined with respect to the crossover distances to derive the satellite-addressable traffic. For MTS voice, an additional amount of traffic was removed to reflect the effect of the existing terrestrial plant-in-place on the satellite-addressable traffic. This effectively decreases the amount of traffic defined as satellite-addressable by 76 percent in 1980 and by 32 percent in 2000. The NASA forecast for satellite-addressable traffic followed a similar procedure. The results are presented in tables II to IV. The two contractors' assumptions, rationale, and crossover distances were examined and compared. The most appropriate (in NASA's judgment) elements of each approach were adopted and the process applied to the NASA net long haul forecast.

The total satellite-addressable voice traffic in table II is the voice traffic addressable by both trunking and CPS systems (overall satellite-addressable). The CPS segment constitutes less than 1 percent of the total. Also, the CPS segment does not include any MTS residential or broadcast radio services. This satellite-addressable traffic is that addressable by an optimum combination of C, Ku, and Ka-band trunking and CPS terminals (both shared and unshared).

Table III shows the traffic addressable by trunking systems alone, without competition from CPS systems. These results are identical with the trunking segment of the overall satellite-addressable traffic (table II), indicating that, for voice, CPS systems are not competitive with trunking systems for inter-SMSA traffic but can address some traffic from the hinterlands.

The satellite-addressable CPS traffic shown in table IV is that amount of traffic addressable by CPS systems alone, ignoring competition from trunking systems. Note that, in the absence of competition from trunking systems, the CPS-addressable demand has increased markedly over the CPS segment of the overall satellite-addressable demand. This indicates that CPS systems can compete for traffic that otherwise would have gone via terrestrial systems, but they are not very competitive with satellite trunking systems. Although an unrealistic case, CPS (alone) systems were investigated to explore the limits of CPS satellite-addressable demand. CPS (alone) systems were also examined specifically in the context of Ka-band. The crossover economics and user acceptance characteristics (particularly for the lower availability case, 0.995) shifted in such a way as to cause the Ka-band CPS-addressable traffic to be somewhat less than the overall CPS (alone)-addressable traffic. The CPS systems are business systems only and consequently carry no residential or radio type traffic. A small amount of mobile phone traffic is carried by the year 2000. There is an increasing degree of connection with time of CPS systems to the wireline switched system thereby increasing the attractiveness of CPS.

Data Services

Total and Net Long Haul Data Demand

WU identified 17 data services and UST&T 6, but UST&T's service categories were at a higher level of aggregation than WU's and encompass a number of the WU services. Even so, it appears that WU identified some additional data sources and their source data forecast in terabits/year (10^{12} bits/year) is about twice that of UST&T by the year 2000. The NASA data forecast retains the 17 WU service categories and adopts the UST&T classification of services as computer and message-type traffic (fig. 1). The computer category is further classified as CPU/CPU and terminal/CPU. Since the WU data forecast was more inclusive, it was adopted as the NASA "total" data forecast. The data totals for the three years 1980, 1990, and 2000 were rounded to the nearest hundred terabits/year. Table V presents the NASA "total" data forecast in terms of terabits/year.

After estimating the "total" data services traffic, both study contractors chose to convert their estimates from bits/year to peak-hour megabits/second (Mbps). As in voice, in converting from source units to transmission capacity, peak-hour factors, transmission efficiency factors, and hours/year of use were combined with the source data to produce the peak-hour megabits/second contribution of each data service category.

In practice, there is a tremendous variation in the efficiency of use of the transmission system among the data service applications, efficiency being defined as the average bit/second throughput relative to the actual transmission capacity of the data channel. Some services such as high speed CPU/CPU data transfer use the transmission facilities very efficiently. Others, such as terminal/CPU applications, are very inefficient in terms of the above definition, since a human operator can generate only a very small bit rate relative to the available capacity of even a low speed data line connecting him with a computer. Depending on assumptions about the future degree of multiplexing of these types of services, the inherent inefficiencies can drive the magnitude of the required transmission capacity out of all proportion to the underlying source data. WU and UST&T had quite different outlooks on how this type of data transmission would be conducted and its influences on future transmission

system capacity requirements. UST&T chose to be very conservative in forecasting improvements in these efficiencies through technology, multiplexing techniques, or system advancements. All of the terminal/CPU data service applications were assumed to require a voice capacity line per user, even in the year 2000. Although they assumed some multiplexing, packet switching, etc., most terminal/CPU applications were assumed to be conducted over conventional switched network and private line facilities. This means the user has exclusive use of the switched circuit during the connect time with no sharing of the line's capacity with other low bit rate users. Terminal/CPU applications over private lines are even more inefficient in this sense as the lines are always reserved for the users whether they use them or not. Thus, in the UST&T forecasts, the relatively smaller amount of terminal/CPU source data dominates the total data forecast when transformed into capacity requirements. Western Union, on the other hand, made the conversion from source data (terabits/year) to peak-hour megabits/second assuming highly efficient Integrated Services Digital Networks (ISDN) employing a high degree of multiplexing and time sharing. Thus, even though WU forecasted a higher amount of source data than UST&T, the UST&T peak-hour conversion resulted in a much higher capacity requirement than WU.

NASA feels that a realistic estimate with respect to the type of data systems in place and the way in which data will be transmitted in the future lies somewhere between the WU and UST&T assumptions. It appears that by the year 2000 most trunking and all CPS satellite communications systems will be highly efficient ISDN systems. Also, during the 1980 to 2000 time period, there will likely be a mix of relatively inefficient systems and more efficient systems, the mix tending to be the more efficient with time. It is expected that the CPS system mix will be somewhat more efficient than the trunking mix as there will be fewer intermediate connections in the transmission links, the CPS systems will be more specifically designed for data transfer, and innovation in the more established trunking systems will occur more slowly. For trunking, NASA chose an inefficient/efficient percent mix of 50/50 for 1980 and 10/90 for the year 2000. For CPS, the mix was chosen to be 30/70 for 1980 and 0/100 for 2000. The above percentages and intermediate values for 1990 were used as weighting factors in deriving from the UST&T and WU efficiency factors a set of efficiency factors to convert the NASA source data forecast (terabits/year) to peak-hour Mbps. Although only part of the total and net long haul data demand is satellite-addressable, the estimates of this demand were initially all converted to peak-hour Mbps in order to maintain common units throughout the analysis. For this conversion, the CPS system efficiency factors were used. This results in slightly more conservative traffic demand values than using trunking efficiency factors. Table VI presents the total and net long haul data forecasts in peak-hour Mbps when using the CPS system efficiency factors.

Satellite-Addressable Data Demand

The satellite-addressable data traffic was derived from the net long haul traffic in the same way as that for the voice traffic. Tables VII and VIII present the satellite-addressable forecasts for data potentially carried by trunking and CPS systems, for each of the 17 data services. For data, the difference between consideration of each system alone or together is significant. Table VII presents the results in the context of both system types competing for the traffic, and the overall satellite demand potential is the sum

of the two. Table VIII presents the results for the maximum potential satellite capture for each system alone, without competition from the other system. Table VIII also includes the demand estimates for Ka-band CPS (alone) systems (totals only). The results (tables VII and VIII) indicate that when both CPS and trunking systems are considered together in a competitive environment, CPS systems dominate the satellite-addressable data demand. In fact, the CPS segment comprises about 95 percent of the overall satellite-addressable data demand. The competitiveness of CPS systems, however, is masked in table VIII because the relatively lower data transmission efficiencies of trunking systems distort a direct comparison of the trunking and CPS demands in terms of peak-hour Mbps. These results indicate that CPS systems can capture data traffic from terrestrial systems that satellite trunking systems cannot. The apparent contradiction of the trunking total for the year 2000 being greater than the NLH shown in table VI is due to the lower transmission efficiencies assumed for trunking. The Total and NLH estimates are based on the relatively higher CPS transmission efficiencies and are not directly comparable to the trunking numbers.

Video Services

All of the video services considered in the forecasts are, by nature, long haul and suitable for transmission by satellite. Therefore, for video, the total, net long haul, and overall satellite-addressable forecasts are identical. Both broadcast video and videoconferencing may be carried by satellite trunking systems but only videoconferencing services appear suitable for transmission by CPS systems.

Video Broadcast Services

Forecasts for the video broadcast services listed in figure 1 were made by the contractors on the basis of current trends, announced plans, and anticipated needs. NASA examined the relative merits of each approach in the light of some more current developments and made adjustments to the forecasts.

Commercial network TV is currently transitioning from program distribution by terrestrial microwave facilities to distribution via satellite systems. Economics and the flexibility of program origination locations appear to favor the choice of satellite systems as the primary medium of network program origination and distribution in the future. The networks also create a demand for occasional transponder usage, but this is accounted for in the "occasional" category.

The Public Broadcasting Service channel requirements were based on their current plans and probable needs.

The study contractors' forecasts for CATV demand were created during a period when the outlook for CATV was somewhat more bullish than it is today. During the last two years, the demand has not developed as earlier anticipated and some companies have left the field. Consequently, the original forecasts were scaled back from 130 channels (an average of the contractors' original estimates) to 85 channels for the year 2000. Also, Direct Broadcast Satellite (DBS) entertainment video was not explicitly considered in the contractors' studies. In this report, the NASA forecast assumes at least 15 channels for low to medium powered DBS in the Fixed Service Satellite (FSS) band by the year

2000, and includes it in the CATV category to raise the total to 100 channels. The proposed high power DBS (on the order of 100 or more watts/channel) services are assigned frequencies outside the FSS bands and hence were not forecast for this report.

Occasional TV represents the additional demand for channels by the networks, PBS, CATV and others for special event coverage on a nonregularly scheduled basis. The projected demand is based on current trends and is related to the growth of the other broadcast services.

The educational services are comprised of degree oriented and post graduate college education, continuing professional education, adult education, seminars, vocational training programs, and more specialized programming aimed at specific groups and applications. Educational video is comprised of applications primarily requiring one-way point-to-point or broadcast transmissions. In some cases, voice feedback from the audience is needed, requiring a return voice link either through the video delivery system or the terrestrial network. This is operationally similar to one-way videoconferencing with narrowband feedback, and for the NASA forecast a large part of the interstate and specialized education requiring voice feedback is placed in the one-way videoconferencing category. The more formal, regularly scheduled educational services are retained for the Educational Services category. Regional and national educational services could account for one national channel plus three regional channels by 1990, and two national plus seven regional channels by the year 2000, for a total channel requirement of 1, 4, and 9 for the years 1980, 1990, and 2000, respectively. In addition, as of 1982, three states were using satellite video transmission for education. Projecting this to grow according to UST&T's projected intrastate educational growth rate results in an overall need for 24 and 80 channels in 1990 and 2000, respectively. Nonsimultaneous and off peak-hour usage would reduce this by a factor of 3 to an effective channel requirement of 1, 8, and 27 for the years 1980, 1990 and 2000.

The UST&T Public Services video category includes two services: telemedicine and public affairs. Public affairs consists of public forums, congressional/constituent meetings, opinion polls, consumer and related activities. It also is very analogous to one-way videoconferencing with voice feedback and is included in that category in the NASA forecast. Therefore, telemedicine is the only public service considered in the NASA broadcast forecast, and it is expected to have a requirement of 12 channels by the year 2000.

Three full motion channels could be devoted to services providing video for home recording by the year 2000.

Videoconferencing Services

Videoconferencing services are categorized as either one-way (one-way video with voice feedback) or two-way video. In addition, the video transmission can be of any speed category from full motion to slow scan. Here, full motion is intended to mean a minimum picture quality of the same order as that provided by CATV transmissions.

One-way videoconferencing. - One-way videoconferencing consists of full motion, limited motion, and slow scan video with voice feedback. It is used for public service, educational, and business applications. In the NASA fore-

cast, the public service and educational components of one-way videoconferencing were drawn from the UST&T study while the business component was based on the WU study. The split between full motion, limited motion, and slow scan for public affairs and educational one-way videoconferencing is based on the UST&T estimates and that for the business portion on the WU estimates. Table IX shows the percent mix of channel speeds for the aggregate one-way videoconferencing demand.

<u>Two-way videoconferencing</u>. - The two study contractors' forecasts of the number of two-way videoconferences/year were very similar. Consequently, for the NASA forecast these were averaged and then combined with the contractors findings on expected conference length (hours), daily peak to average ratios, and number of days/year of use to obtain the equivalent channel requirements by year. The split among full motion, limited motion, and slow scan is based on the WU split for business services. Table X shows the percent mix of channel speeds for two-way videoconferencing.

As indicated earlier, the only video service carried by CPS systems is videoconferencing. The amount of CPS-suitable videoconferencing demand was estimated by considering the contractors' estimates of the fraction of the total carried by CPS systems. Likewise, the Ka-band CPS videoconferencing demand for dedicated and shared earth stations at the two service availability levels, 0.999 and 0.995, is based on a combination of the contractors' results.

Table XI summarizes the NASA forecasted overall satellite-addressable video demand for the broadcast and videoconferencing services in terms of the number of channels required. The overall satellite-addressable video demand is comprised of a trunking segment containing both broadcast and videoconferencing services and a CPS segment consisting of only videoconferencing services. The trunking segment of the overall is identical to the trunking alone video demand (table XII). The CPS segment of the overall is small, about 5 percent, while the CPS alone video demand (table XIII) is significantly higher due to the assumed lack of competition from trunking systems. As mentioned earlier, the total, net long haul, and overall satellite-addressable video demands are considered identical.

Equivalent 36 MHz Transponders

The satellite-addressable demand in terms of voice half circuits, megabits/second for data, and number of video channels was converted into a transmission system capacity equivalent of 36 MHz transponders. Thus, the three service categories, voice, data and video, can then be summed in terms of the common units of 36 MHz transponders to obtain the total equivalent satellite capacity requirements. Forecasts of expected improvements in encoding, modulation, video compression, and relative percents of analog and digital traffic were made by WU. For each base year, 1980, 1990, and 2000, the expected mix of technology capability in service was estimated. For voice (analog), large improvements in transponder throughput are possible using companded single sideband (CSSB) techniques. Presently, about 1200 voice half circuits/transponder is typical for trunking systems, but CSSB techniques allow up to 7000 or more. Digital encoding techniques may permit a reduction in transmission rate from the present 64 Kbps to the order of 24 Kbps for digitized voice by the year 2000. CPS systems are likely to be all digital, while the large trunking systems are expected to carry voice as a 50/50 mixture of CSSB and digital. For trunking systems, transponder data rate throughputs are expected

to increase from 60 to 90 Mbps if transmitted TDMA or from 54 to 81 Mbps for FDMA during the 1980 to 2000 time frame. Likewise, for CPS systems, transponder capacities are expected to increase from 36 to 52.5 Mbps. The transponder throughputs for CPS systems are lower than for trunking because CPS generally operates with multiple carriers (that is, from a large number of small earth terminals) per transponder while trunking is single carrier/transponder.

Video compression techniques will continue to reduce the capacity necessary to transmit full motion video. Typically, one channel/36 MHz transponder has been used, but 24 to 27 MHz is now recognized as completely adequate and is expected to be widely adopted for high quality video in the future. Also, techniques are being developed for transmitting two network quality signals/36 MHz transponder that appear very promising. Three video channels/transponder can be transmitted with some degradation, but is still adequate for full motion in some applications. Videoconferencing is composed of full motion, limited motion, and slow scan channels. The full motion forecast varies from one to three one-way video channels/equivalent 36 MHz transponder over the time period. Limited motion comprises a variety of channel speeds that are less than true full motion but greater than slow scan, with the average speed requirement varying from 5.0 Mbps/channel in 1980 to 2.5 Mbps in the year 2000. The average slow scan speed is assumed to be 56 Kbps initially. Again, although the channel data rates are the same for CPS and trunking systems, fewer channels/transponder are carried by the CPS systems because CPS systems operate with multiple carriers/transponder. Tables XIV and XV summarize the technology improvement assumptions used to convert the demand estimates to equivalent 36 MHz transponders. These assumptions represent the mix of technologies in use during each year, not the then state-of-the-art capabilities.

RESULTS AND DISCUSSION

The final results of the forecasts are presented in tables XVI to XXIV. Tables XVI to XX present summaries of the voice, data, and video results in the basic units of thousands of half circuits, peak-hour megabits/second, and video channels, respectively, while tables XXI to XXIV present the results in terms of their equivalent capacities in 36 MHz transponders. As stated previously, the satellite-addressable traffic forecasts presented in these tables are not estimates of that traffic which <u>will</u> be captured by satellite systems but rather they are estimates of that volume of traffic which <u>could</u> be captured by satellite system operators based on system economic and technical characteristics.

Table XVI presents the forecasts for the total U.S. domestic (excluding nontoll) peak-hour demand or capacity requirements for voice, video, and data. The business-oriented voice services appear to exceed the residential requirement by an order of magnitude, but this merely reflects the fact that the busy hour (peak) for each service type occurs at a different time of day, with the business busy hour dominating. During the evening, the residential requirement dominates, but the total of business and residential is at a maximum during the business day, and hence the peak hour and peak-hour demand composition (shown in table XVI) occurs during that time. The voice traffic contributed by the six services in the "Other" category contributes less than 1 percent to the total voice. The total voice demand, as measured in half circuits, grows by a factor of 6.75 from 1980 to 2000 or an average annual growth rate of 10 percent over the 20-year period.

The data forecasts are presented for each of the 17 data services in terms of peak-hour megabits/second. Two factors influencing the forecasted data traffic growth with time are the underlying growth in demand, i.e., bits generated/year (table V), and improvements in efficiency of transmission. Although the basic demand grows by a factor of 15 over the period from 1980 to 2000, the dominating influence of transmission efficiency improvements causes the transmission capacity requirement, expressed in peak-hour megabits/second, to exhibit a peak and then decline somewhat beyond 1990. This effect is illustrated by comparing table V with tables VI or XVI. This is a characteristic of the total and net long haul traffic only, however, as the satellite-addressable fraction of the capacity requirement is expected to grow through the year 2000.

The demand for broadcast video channels grows at a rate of about 11 percent/year during the 1980's and then levels off to about 4 percent/year during the 1990's as the networks and CATV operators' satellite systems are established and the desire for additional programming is satisfied.

Tables XVII to XIX present the forecast results for voice, data and video, respectively, by hierarchical order of total, net long haul, overall satellite-addressable, trunking and CPS segments of the overall, trunking satellite-addressable alone, CPS satellite-addressable alone, and Ka-band CPS satellite-addressable alone at the two service availability levels of 0.999 and 0.995. The Ka-band CPS forecasts include the demand estimates for unshared earth stations as well as for the combination of shared and unshared earth terminals yielding the greatest demand potential. The Ka-band CPS alone satellite-addressable demand potential is reduced somewhat from the CPS alone due to system economics and service availability. Table XX summarizes the voice, data, and video service totals by hierarchical order.

Tables XXI to XXIV express the results shown in tables XVII to XX in terms of equivalent 36 MHz transponders. With the three services in common units of 36 MHz transponders, they may be summed to obtain the total demand potential. This total for each hierarchical order is presented in table XXIV and also figure 4. Note that even with technological improvements moderating the translation of the underlying demand into equivalent satellite system capacity, the overall satellite-addressable demand increases six-fold from 1980 to 2000. Due to the trunking and CPS system economics employed in the study, the results for the voice and video segments of the trunking segment of the overall satellite-addressable demand are identical to those for trunking systems alone. Data, on the other hand, was found, in general, to be more economically transmitted by CPS systems. In fact, the entire CPS segment of the overall satellite-addressable demand for 1980 is comprised of data, and in 2000 it is 93 percent data (table XXIV). Also, the CPS segment is quite a bit smaller than the overall satellite-addressable demand, growing from about 8 percent of the overall in 1980 to 21 percent in the year 2000.

Table XXV and figure 5 are provided for a comparison of the NASA forecast results with those of the two study contractors, WU and UST&T, in terms of 36 MHz transponders. The relatively high transponder forecast of UST&T for NLH is due to their comparatively conservative assumptions concerning data transmission efficiency.

The somewhat lower NASA forecast for overall satellite-addressable demand for the year 2000 came about through a combination of lower basic demand forecasts for some services and more optimistic technology forecasts permitting

greater throughput/transponder. WU made the highest forecast for voice services while the NASA forecast is somewhat less. The UST&T forecast for data was the highest (in terms of transponders) due to their relatively conservative transmission efficiency factor assumptions. Also, the NASA forecast of video throughput/transponder is more optimistic, resulting in a lower transponder estimate for video. Thus, the sum of the overall satellite-addressable voice, data, and video demands for the NASA forecast is lower than either that of WU or UST&T.

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TABLE I. - TOTAL AND NET LONG HAUL VOICE DEMAND, PEAK-HOUR 10^3 HALF CIRCUITS

Total			
	1980	1990	2000
MTS residential	89.3	215.3	474.4
MTS business and WATS	1616.5	4222.7	9 841.8
Private line	870.9	2765.2	7 000
Other			
Mobile telephone	1.4	36.7	117.6
Public radio	.3	1.8	2.6
Commercial and religious	.5	2	3.2
Occasional	1.2	2.4	3.7
CATV (music)	.1	.3	1.2
Recording	.0	.0	.9
	2580	7245	17 444
Net Long Haul			
	1980	1990	2000
MTS residential	81.9	197.5	434.3
MTS business and WATS	1431.8	3992.8	9 366
Private line	766	2546	6 603
Other			
Mobile telephone	1.3	34.9	111.8
Public radio	.3	1.8	2.6
Commercial and religious	.5	2	3.2
Occasional	.9	1.8	2.7
CATV (music)	.1	.3	1.2
Recording	.0	.0	.4
	2283	6777	16 526

TABLE II. - OVERALL SATELLITE-ADDRESSABLE VOICE DEMAND, PEAK-HOUR 10^3 HALF CIRCUITS

	1980	1990	2000
MTS residential	7.6	34.1	114.3
MTS business and WATS	184.7	934.4	3344.4
Private line	176	840	3302
Other			
Mobile telephone	.6	18.8	80.2
Public radio	.3	1.8	2.6
Commercial and religious	.5	2	3.2
Occasional	.9	1.8	2.7
CATV (music)	.1	.3	1.2
Recording	.0	.0	.4
	371	1833	6851
Trunking segment	371	1828	6816
CPS segment	0	5	35

TABLE III. - TRUNKING (ALONE) SATELLITE-ADDRESSABLE VOICE DEMAND, PEAK-HOUR 10^3 HALF CIRCUITS

	1980	1990	2000
MTS residential	7.6	34	114
MTS business and WATS	184.7	932	3327
Private line	176	837	3285
Other			
Mobile telephone	.6	18.8	80.2
Public radio	.3	1.8	2.6
Commercial and religious	.5	2	3.2
Occasional	.9	1.8	2.7
CATV (music)	.1	.3	1.2
Recording	.0	.0	.4
	371	1828	6816

TABLE IV. - CPS (ALONE) SATELLITE-ADDRESSABLE VOICE DEMAND, PEAK-HOUR 10^3 HALF CIRCUITS

		1980	1990	2000
MTS business and WATS		4.9	36.6	261.5
Private line		.6	40.2	231
Mobile telephone		0	0	2.5
		5.5	76.8	495
Ka-band CPS:				
sh/unsh	MTS (Bus and WATS)	0	22.3	160
0.999	Pvt. line	.55	40.2	231
avail.		0.55	62.5	391
unsh	MTS (Bus and WATS)	0	6.6	80.2
0.999	Pvt. line	.28	13.5	85.8
avail.		0.28	20.1	166
sh/unsh	MTS (Bus and WATS)	0	15	108
0.995	Pvt. line	.37	27.1	155.9
avail.		0.37	42.1	263.9
unsh	MTS (Bus and WATS)	0	4.5	54.1
0.995	Pvt. line	.16	9.1	57.9
avail.		0.16	13.6	112

Note: The MTS Residential category and the Radio portion of the other category are not addressable by CPS systems.

TABLE V. - TOTAL DATA DEMAND,
TERABITS/YEAR

	1980	1990	2000
Computer			
Terminal/CPU			
Data entry	383	2168	8 107
Remote job entry	166	1414	2 629
Inquiry/Response	166	1463	3 516
Timesharing	95	277	509
Point of sale	12	257	436
Videotex	.1	322	1 164
Telemonitoring	.1	.8	3.4
	822	5900	16 364
CPU/CPU			
Data transfer	460	1320	6 550
Batch processing	300	706	2 310
	760	2026	8 860
Message			
USPS EMSS	58	380	948
Mailbox	.2	5	13
Administrative	47	300	974
TWX/Telex	1	1.2	1.5
Facsimile	187.4	600	1 423
Mailgram, etc.	.4	.8	1.8
Com. Word Proc.	19	124	490
Secure voice	5.3	163	924
	318	1574	4 775
Total	1900	9500	30 000

TABLE VI. - TOTAL AND NET LONG HAUL DATA DEMAND, PEAK-HOUR Mbps

Total			
	1980	1990	2000
Data entry	35 466	37 525	30 918
Remote job entry	5 668	5 794	2 863
Inquiry/Response	7 526	7 959	5 083
Timesharing	4 307	1 507	736
Point-of-sale	355	2 975	2 398
Videotex	2.5	969	931
Telemonitoring	1.2	3.9	16
Data transfer	108	165	590
Batch processing	1 263	324	306
USPS EMSS	31	143	244
Mailbox	12	121	150
Administrative	4 630	11 575	17 895
TWX/Telex	6	.8	.5
Facsimile	443	945	1 120
Mailgram, etc.	.2	.3	.5
Com. Word Proc.	35	115	227
Secure voice	1	35	201
Total data	59 855	70 157	63 679
Net Long Haul			
	1980	1990	2000
Data entry	14 186	15 010	12 367
Remote job entry	3 684	3 760	3 304
Inquiry/Response	3 763	3 980	2 542
Timesharing	3 015	1 055	515
Point-of-sale	107	893	719
Videotex	2.5	969	931
Telemonitoring	.3	1	4
Data transfer	91	139	496
Batch processing	1 010	259	245
USPS EMSS	31	143	244
Mailbox	9	91	113
Administrative	2 778	6 945	10 737
TWX/Telex	6	.8	.5
Facsimile	399	851	1 008
Mailgram, etc.	.2	.3	.5
Com. Word Proc.	25	81	159
Secure voice	1	32	181
Total data	29 108	34 216	33 566

Note: CPS transmission efficiencies were used in deriving the peak-hour Mbps from the source data in terabits/year.

TABLE VII. - SATELLITE-ADDRESSABLE DATA DEMAND, PEAK-HOUR Mbps
TRUNKING SEGMENT, CPS SEGMENT AND OVERALL

	1980			1990			2000		
	Tr	CPS	Overall	Tr	CPS	Overall	Tr	CPS	Overall
Data entry	0	618	618	0	6 162	6 162	0	11 163	11 163
Remote job entry	0	186	186	0	1 544	1 544	0	1 674	1 674
Inquiry/Response	0	76	76	0	634	634	0	752	752
Timesharing	0	65	65	0	160	160	0	170	170
Point-of-sale	0	5	5	0	335	335	0	573	573
Videotex	0	0	0	1231	0	1 231	2816	0	2 816
Telemonitoring	0	0	0	0	1	1	0	3	3
Data transfer	0	4	4	64	14	78	342	41	383
Batch processing	0	50	50	0	128	128	140	19	159
USPS/EMSS	0	0	0	37	7	44	29	100	129
Mailbox	0	0	0	0	37	37	0	98	98
Administrative	0	158	158	0	3 095	3 095	0	9 686	9 686
TWX/Telex	0	1	1	20	0	20	21	0	21
Facsimile	0	23	23	0	230	230	0	453	453
Mailgram/etc.	0	0	0	0	0	0	0	0	0
Com. Word Proc.	0	1	1	0	36	36	0	145	145
Secure voice	0	1	1	0	13	13	0	161	161
Total	0	1187	1187	1352	12 396	13 748	3348	25 038	28 386

Note: This represents the satellite-addressable demand potential for coexisting trunking and CPS systems, overall = trunking + CPS.

TABLE VIII. - SATELLITE-ADDRESSABLE DATA DEMAND, PEAK-HOUR Mbps TRUNKING (ALONE) AND CPS (ALONE)

	Trunk.	CPS	Trunk.	CPS	Trunk.	CPS
Data entry	545	618	7 477	6 162	16 945	11 163
Remote job entry	222	186	4 831	1 544	5 157	1 674
Inquiry/Response	91	76	2 009	633	2 587	752
Timesharing	76	65	514	160	587	170
Point-of-sale	5	5	346	316	534	573
Videotex	0	0	1 231	0	2 815	0
Telemonitoring	0	0	0	1	3	3
Data transfer	7	4	64	58	342	413
Batch processing	63	50	407	128	1 907	140
USPS/EMSS	0	0	37	28	136	100
Mailbox	0	0	37	37	85	98
Administrative	138	158	3 036	3 095	8 118	9 686
TWX/Telex	28	1	20	8	21	10
Facsimile	20	16	326	165	508	453
Mailgram/etc.	0	0	0	0	0	0
Com. Word Proc.	1	1	27	36	97	145
Secure voice	0	0	10	13	90	161
Total	1196	1180	20 372	12 384	40 534	25 541
Ka-Band CPS Satellite-Addressable (Totals)						
sh/unsh 0.999 avail.	970		10 870		21 743	
unsh 0.999 avail.	970		10 870		21 743	
sh/unsh 0.995 avail.	485		5 335		10 872	
unsh 0.995 avail.	485		5 335		10 872	

Note: (1) This represents the independent satellite-addressable demand potential of trunking and CPS systems; here trunking and CPS are nonadditive. (2) The trunking totals are not directly comparable to the Total and Net Long Haul estimates of Table VI, as different transmission efficiencies were assumed for trunking. The relatively higher CPS data transmission efficiencies were used in deriving the Total and Net Long Haul values.

TABLE IX. - PERCENT MIX OF ONE-WAY VIDEOCONFERENCING CHANNELS BY CHANNEL SPEED

	1980	1990	2000
Full motion	100	63	14
Limited motion	0	37	86
Slow scan	0	0	0
	100	100	100

TABLE X. - PERCENT MIX OF TWO-WAY VIDEOCONFERENCING CHANNELS BY CHANNEL SPEED

	1980	1990	2000
Full motion	60	6	1
Limited motion	10	70.5	76
Slow scan	30	23.5	23
	100	100	100

TABLE XI. - TOTAL (OVERALL SATELLITE-ADDRESSABLE) VIDEO DEMAND PEAK-HOUR CHANNEL REQUIREMENT

	1980	1990	2000
Broadcast video:			
Network commercial	6	14	20
Network noncommercial (PBS)	3	4	5
CATV	32	80	100
Occasional	14	42	57
Education	2	12	36
Public service	0	6	12
Recording channel	0	0	3
Total broadcast video	57	158	233
Videoconferencing:			
One-way: Full motion	1	41	31
Limited motion	0	71	194
Total one-way	1	112	225
Two-Way: Full motion	2	112	80
Limited motion	0	1310	6080
Slow scan	0	437	1840
Total two-way	2	1859	8000
Total videoconferencing	3	1971	8225
Total video	60	2129	8458
Trunking segment	60	2058	8047
CPS segment	0	71	411

Notes: (1) Total video, net long haul, and satellite-addressable are identical. (2) CPS systems carry only videoconferencing traffic.

TABLE XII. - TRUNKING (ALONE) SATELLITE-
ADDRESSABLE VIDEO DEMAND PEAK-HOUR
CHANNEL REQUIREMENT

	1980	1990	2000
Broadcast video	57	158	233
Videoconferencing:			
One-way: Full motion	1	40	30
Limited motion	0	68	184
Total one-way	1	108	214
Two-Way: Full motion	2	108	76
Limited motion	0	1263	5776
Slow scan	0	421	1748
Total two-way	2	1792	7600
Total videoconferencing	3	1900	7814
Total video	60	2058	8047

TABLE XIII. - CPS (ALONE) SATELLITE-
ADDRESSABLE VIDEO DEMAND PEAK-HOUR
CHANNEL REQUIREMENT

	1980	1990	2000
Broadcast video	0	0	0
Videoconferencing:			
One-way: Full motion	0	8	7
Limited motion	0	13	47
Total one-way	0	21	54
Two-Way: Full motion	0	21	19
Limited motion	0	247	1458
Slow scan	0	82	441
Total two-way	0	350	1918
Total CPS video	0	371	1972
Ka CPS, shared/unshared	0	313	1654
0.999 unshared	0	313	1654
Ka CPS, shared/unshared	0	157	827
0.995 unshared	0	157	827

TABLE XIV. - VOICE AND DATA TRANSPONDER (36 MHz) THROUGHPUT FORECASTS

	1980	1990	2000
Voice			
Trunking half circuits/ 36 MHz Transponder			
Analog	1200	3000	6000
Digital	844	2531	3375
Percent Analog	100	75	50
Digital	0	25	50
CPS (all digital) half circuits/ 36 MHz transponder	562	1640	2187
Digital voice data rate, Kbps	64	32	24
Data			
Trunking transponder, Mbps	54	81	81
CPS transponder, Mbps	36	52.5	52.5

TABLE XV. - VIDEO CHANNEL TRANSPONDER (36 MHz) THROUGHPUT FORECASTS

	1980	1990	2000
Broadcast			
Network	1	1	2
CATV	1	2	3
Occasional	1	1	2
Education	1	2	3
Public service	1	2	3
Recording channel	1	2	3
Videoconferencing trunking			
Full motion	1	2	3
Limited motion	12	24	36
Slow scan	300	600	900
CPS			
Full motion	1	1	2
Limited motion	7	14	21
Slow scan	180	350	525

TABLE XVI. - TOTAL U.S. DOMESTIC TELECOMMUNICATIONS DEMAND

	1980	1990	2000
Voice, 10^3 half circuits			
MTS residential	89.3	215.3	473.4
MTS bus and WATS	1616.5	4222.7	9 841.8
Private line	870.9	2765.2	7 000
Other	3.5	43.2	129.2
Total voice	2580	7245	17 444
Data, peak hour Mbps			
Data entry	35 466	37 525	30 918
Remote job entry	5 668	5 794	2 863
Inquiry/Response	7 526	7 959	5 083
Timesharing	4 307	1 507	736
Point-of-sale	355	2 975	2 398
Videotex	2.5	969	931
Telemonitoring	1.2	3.9	16
Data transfer	108	165	590
Batch processing	1 263	324	306
USPS EMSS	31	143	244
Mailbox	12	121	150
Administrative	4 630	11 575	17 895
TWX/Telex	6	.8	.5
Facsimile	443	945	1 120
Mailgram, etc.	.2	.3	.5
Com. Word Proc.	35	115	227
Secure voice	1	35	201
Total data	59 855	70 157	63 679
Video, channels			
Broadcast	57	158	233
One-way videoconferencing	1	112	225
Two-way videoconferencing	2	1859	8000
Total video	60	2129	8458

Notes: (1) Non-toll telephone voice/data traffic is excluded, (2) Videoconferencing contains a wide mix of channel speeds.

TABLE XVII. - VOICE FORECAST SUMMARY,

PEAK-HOUR 10^3 HALF CIRCUITS

	1980	1990	2000
Voice			
Total voice			
MTS (Residential)	89.3	215.3	473.4
MTS (Business and WATS)	1616.5	4222.7	9841.8
Pvt. line	870.9	2765.2	7000
Other	3.5	43.4	128.2
	2580	7,245	17,444
Net long haul			
MTS (Res)	81.9	197.5	434.3
MTS (Bus and WATS)	1431.8	3992.8	9366
Pvt. line	766.0	2546.0	6603
Other	3.1	40.8	121.9
	2283	6,777	16,526
Satellite addressable			
Overall			
MTS (Res)	7.6	34.1	114.3
MTS (Bus and WATS)	184.7	934.4	3344.4
Pvt. line	176	840	3302
Other	2.4	24.7	90.3
	371	1833	6851
Trunking segment	371	1828	6816
CPS segment	0	5	35
Trunking alone	371	1828	6816
CPS alone	5.5	76.8	495
Ka CPS			
0.999 sh/unsh	.55	62.5	391
unshared	.28	20.1	166
0.995 sh/unsh	.37	42.1	263.9
unshared	.16	13.6	112

TABLE XVIII. - DATA FORECAST SUMMARY,
PEAK-HOUR Mbps

	1980	1990	2000
Total	59 855	70 157	63 679
Net long haul	29 108	34 216	33 566
Satellite addressable			
Overall	1 187	13 748	28 386
Trunking segment	0	1 352	3 348
CPS segment	1 187	12 396	25 038
Trunking alone	1 196	20 372	40 534
CPS alone	1 180	12 385	25 540
Ka CPS			
0.999 sh/unsh	970	10 870	21 743
unshared	970	10 870	21 743
0.995 sh/unsh	485	5 335	10 872
unshared	485	5 335	10 872

TABLE XIX. - VIDEO FORECAST SUMMARY, PEAK-HOUR CHANNELS

	1980	1990	2000
Broadcast video			
Network commercial	6	14	20
Network noncommercial (PBS)	3	4	5
CATV	32	80	100
Occasional	14	42	57
Education	2	12	36
Public service	0	6	12
Recording channel	0	0	3
Total broadcast video	57	158	233
Videoconferencing:			
One-way	1	112	225
Two-way	2	1859	8000
Total video channels	60	2129	8458
Trunking segment	60	2058	8047
CPS segment	0	71	411
Trunking alone	60	2058	8047
CPS alone	0	371	1972
Ka CPS			
0.999 sh/unsh	0	313	1654
unshared	0	313	1654
0.995 sh/unsh	0	157	827
unshared	0	157	827

Notes: (1) Total video, net long haul, and satellite-addressable are identical; (2) CPS systems carry only videoconferencing video traffic.

TABLE XX. - SUMMARY OF VOICE, DATA AND VIDEO DEMAND FORECASTS

		1980	1990	2000
Total	Voice	2 580	7 245	17 430
	Data	60 000	70 000	63 700
	Video	60	2 129	8 458
Net long haul	Voice	2 283	6 777	16 525
	Data	29 100	34 216	33 566
	Video	60	2 129	8 458
Satellite addressable				
Overall	Voice	371	1 833	6 851
	Data	1 187	13 748	28 386
	Video	60	2 129	8 458
Trunking segment	Voice	371	1 828	6 816
	Data	0	1 352	3 348
	Video	60	2 058	8 047
CPS segment	Voice	0	5	35
	Data	1 187	12 396	25 038
	Video	0	71	411
Trunking alone	Voice	371	1 828	6 816
	Data	1 196	20 372	40 534
	Video	60	2 058	8 047
CPS alone	Voice	5.5	77	495
	Data	1 180	12 385	25 540
	Video	0	371	1 972
Ka CPS	Voice	.5	63	391
sh/unsh	Data	970	10 870	21 743
0.999	Video	0	313	1 654
Ka CPS	Voice	.3	20	166
unsh	Data	970	10 870	21 743
0.999	Video	0	313	1 654
Ka CPS	Voice	.4	42	264
sh/unsh	Data	485	5 335	10 872
0.995	Video	0	157	827
Ka CPS	Voice	.2	14	112
unsh	Data	485	5 335	10 872
0.995	Video	0	157	827

Note: Voice in terms of peak-hour 10^3 half circuits, data in peak-hour megabits/second, and video in peak-hour one-way channels.

TABLE XXI. - VOICE FORECAST SUMMARY, EQUIVALENT 36 MHz TRANSPONDERS

	1980	1990	2000
Total voice			
MTS (Residential)	74	75	110
MTS (Business and WATS)	1347	1473	2278
Pvt. Line	726	969	1620
Other	3	14	27
	2150	2526	4035
Net long haul			
MTS (Res)	68.3	68.9	100.5
MTS (Bus and WATS)	1193.2	1392.7	2168
Pvt. line	638	888	1528.0
Other	2.6	14.2	28.2
	1902	2364	3825
Satellite addressable			
Overall			
MTS (Res)	6.3	11.9	26.4
MTS (Bus and WATS)	154.8	327	791.5
Pvt. line	146.7	294.3	781.5
Other	2	7.8	21.0
	310	641	1594
Trunking segment	310	638	1578
CPS segment	0	3	16
Trunking alone	310	635	1578
CPS alone	10	47	225
Ka-Band CPS alone			
0.999 sh/unsh	1.0	38	179
unsh	.5	12	76
0.995 sh/unsh	.7	26	121
unsh	.3	8	51

TABLE XXII. - DATA FORECAST SUMMARY,
EQUIVALENT 36 MHz TRANSPONDERS

	1980	1990	2000
Total	1663	1336	1213
Net long haul	808	652	639
Satellite addressable			
Overall	33	254	518
Trunking segment	0	17	41
CPS segment	33	237	477
Trunking alone	22	252	500
CPS alone	33	244	486
Ka CPS			
0.999 sh/unsh	28	207	414
unshared	28	207	414
0.995 sh/unsh	14	104	207
unshared	14	104	207

TABLE XXIII. - VIDEO FORECAST SUMMARY,
EQUIVALENT 36 MHz TRANSPONDERS

	1980	1990	2000
Broadcast video:			
Network commercial	6	14	10
Network noncommercial (PBS)	3	4	3
CATV	32	40	33
Occasional	14	42	29
Education	2	6	12
Public service	0	3	4
Recording channel	0	0	1
Total broadcast video	57	109	92
Videoconferencing:			
One-way	1	26	22
Two-way	2	115	198
Total video transponders	60	250	312
Trunking segment	60	240	295
CPS segment	0	10	17
Trunking alone	60	240	295
CPS alone	0	50	91
Ka CPS			
0.999 sh/unsh	0	43	78
unshared	0	43	78
Ka CPS			
0.995 sh/unsh	0	22	39
unshared	0	22	39

Note: Total, Net Long Haul, and Satellite-Addressable video demands are equivalent.

TABLE XXIV. - SUMMARY OF VOICE, DATA, AND VIDEO DEMAND FORECASTS, EQUIVALENT 36 MHz TRANSPONDERS

		1980	1990	2000
Total	Voice	2150	2526	4035
	Data	1663	1336	1213
	Video	60	250	312
	Total	3873	4112	5560
Net long haul	Voice	1902	2364	3824
	Data	808	652	639
	Video	60	250	312
	Total	2770	3266	4775
Satellite addressable				
Overall	Voice	310	641	1594
	Data	33	254	518
	Video	60	250	312
	Total	403	1145	2424
Trunking segment	Voice	310	638	1578
	Data	0	17	41
	Video	60	240	295
	Total	370	895	1914
CPS segment	Voice	0	3	16
	Data	33	237	477
	Video	0	10	17
	Total	33	250	510
Trunking alone	Voice	310	638	1578
	Data	22	252	500
	Video	60	240	295
	Total	392	1130	2373
CPS alone	Voice	10	47	225
	Data	33	244	486
	Video	0	50	91
	Total	43	341	802
Ka CPS sh/unshared 0.999	Voice	1	38	179
	Data	28	207	414
	Video	0	43	78
	Total	29	288	671
Ka CPS unshared 0.999	Voice	.5	12	76
	Data	28	207	414
	Video	0	43	78
	Total	28.5	262	568
Ka CPS sh/unshared 0.995	Voice	.7	26	121
	Data	14	104	207
	Video	0	22	39
	Total	14.7	152	367
Ka CPS unshared 0.995	Voice	.3	8	51
	Data	14	104	207
	Video	0	22	34
	Total	14.3	134	292

TABLE XXV. - COMPARISON OF CONTRACTOR AND NASA FORECASTS, 36 MHz TRANSPONDERS

36 MHz transponders	1980			1990			2000		
	WU	UST&T	NASA	WU	UST&T	NASA	WU	UST&T	NASA
Net long haul	2445	2893	2770	3294	4222	3266	4724	7530	4775
Satellite addressable:									
Overall	273	364	403	1141	1170	1145	2778	3302	2424
Trunking segment	251	----	370	927	----	895	2211	----	1914
CPS segment	22	----	33	214	----	250	567	----	510
Trunking alone	263	----	392	1045	----	1130	2468	----	2373
CPS alone	23	41	43	269	189	341	739	699	802
Ka CPS Sh/unsh 0.999	----	41	29	225	189	288	608	699	671
Ka CPS unshared 0.999	----	17	29	213	77	262	551	283	568
Ka CPS Sh/Unsh 0.995	----	17	15	203	75	152	548	274	367
Ka CPS unshared 0.995	----	7	14	192	31	134	496	111	292

Voice

MTS, Residential

MTS, Business and WATS

Private Line

Other

- Mobile
- Public Radio
- Commercial and Religious
- Occasional
- CATV Music
- Recording

Data

Computer

- Terminal/CPU
  - Data Entry
  - Remote Job Entry
  - Inquiry/Response
  - Timesharing
  - Point of Sale
  - Videotex
  - Telemonitoring
- CPU/CPU
  - Data Transfer
  - Batch Processing

Message

- USPS EMSS
- Mailbox
- Administrative
- TWX/Telex
- Facsimile
- Mailgram
- Communicating Word Processing
- Secure Voice

Video

Broadcast Video

- Network, Commercial
- Network, Non-Commercial (PBS)
- CATV
- Occasional
- Educational
- Public Service (telemedicine)
- Recording Channel

Videoconferencing

- one-way
- two-way
- -- full motion
- -- limited motion
- -- fixed frame

Figure 1. - Telecommunications services forecast in this study

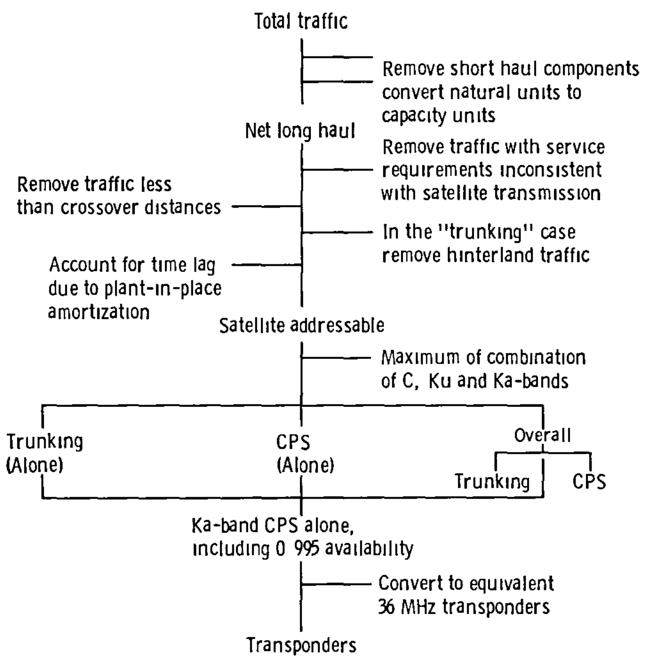

Figure 2 - Satellite addressable traffic derivation process

Tu‹l Demand

Net Long Haul

Satellite Addressable

Overall

Trunking Segment
CPS Segment

Trunking Alone

Customer Premises Service (CPS) Alone

Ka-band CPS
-- shared/unshared, 0 999 availability
-- unshared, 0.999 availability

Ka-band CPS
-- shared/unshared, 0.995 availability
-- unshared, 0 995 availability

Figure 3 - Hierarchical arrangement of demand analysis components

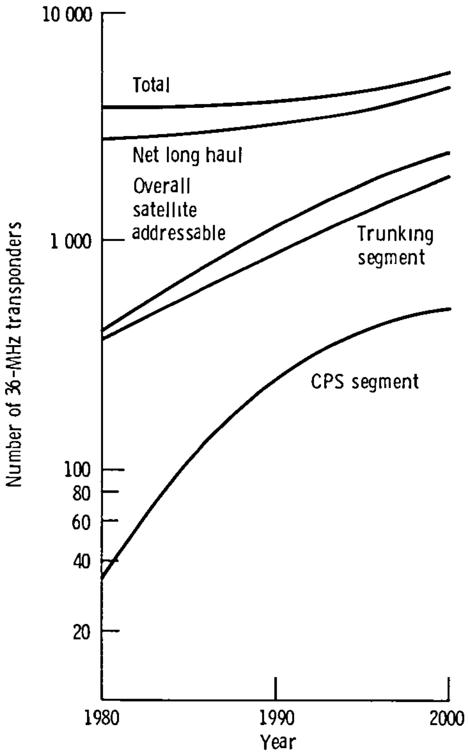

Figure 4. - Telecommunications demand forecasts for 36-MHz transponders.

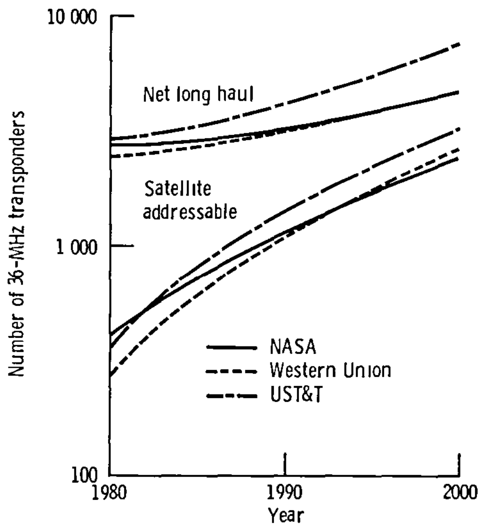

Figure 5 - Comparison of NASA, Western Union, and UST&T telecommunications demand forecasts for 36-MHz transponders.

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16 Abstract

Three fixed service telecommunications demand assessment studies were completed in 1983 for NASA by The Western Union Telegraph Company and the U.S. Telephone and Telegraph Corporation. These studies provided forecasts of the total U.S. domestic demand, from 1980 to the year 2000, for voice, data, and video services. That portion that is technically and economically suitable for transmission by satellite systems, both large trunking systems and customer premises services (CPS) systems was also estimated. In order to provide a single set of forecasts for use in NASA communications program planning, a NASA synthesis of the above studies was conducted and is the subject of this report. The services, associated forecast techniques, and data bases employed by both contractors were examined, those elements of each judged to be the most appropriate were selected, and new forecasts were made. The demand for voice, data, and video services was first forecast in fundamental units of call-seconds, bits/year, and channels, respectively. Transmission technology characteristics and capabilities were then forecast, and the fundamental demand converted to an equivalent transmission capacity. The potential demand for satellite-provided services was found to grow by a factor of 6, from 400 to 2400 equivalent 36 MHz satellite transponders over the 20-year period. About 80 percent of this was found to be more appropriate for trunking systems and 20 percent for CPS.

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